Gamma-Ray Large Area Space Telescope (GLAST)

Mission System Specification
Draft Version 0.3

June 30, 2000

Revision History

Version	Description	Date
0.1	Capture mission parameters	12/8/97
0.2	First full development across all system elements	9/16/99
0.3	Restructured for flowdown to standalone documents for system elements	6/30/00

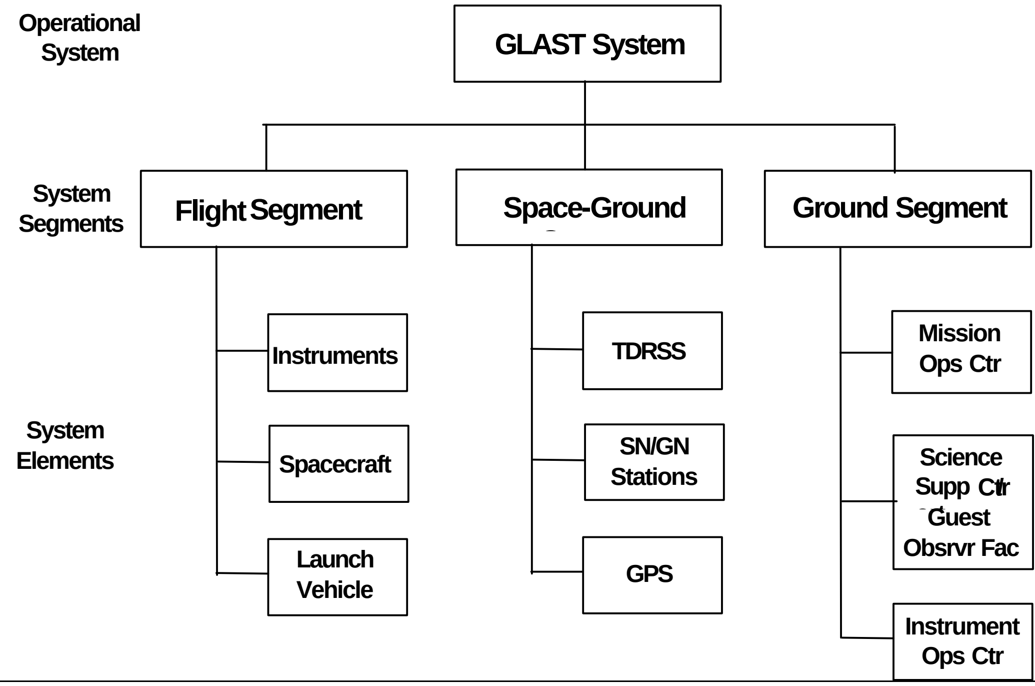
Contents

Object Identifier	MSS		Rqmt Rationale
MSS55	**Acronyms**		
MSS995	AOS	Advanced Orbiting Systems	
MSS56	b	bit	
MSS57	B	Byte	
MSS58	CCSDS	Consultative Committee for Space Data Systems	
MSS59	DN	Data Number	
MSS60	DL	Downlink	
MSS61	EU	Engineering Units	
MSS62	FITS	Flexible Image Transport System	
MSS63	Gb	Gigabit	
MSS994	GBM	Gamma-Ray Burst Monitor	
MSS64	GCN	Gamma Ray Burst Coordinates Network	
MSS65	GLAST	Gamma ray Large Area Space Telescope	
MSS66	GN	Ground Network	
MSS67	GOF	Guest Observer Facility	
MSS68	GPS	Global Positioning System	
MSS69	HEASARC	High Energy Astrophysics Science Archive Research Center	
MSS70	IOC	Instrument Operations Center	
MSS996	LAT	Large Area Telescope	
MSS71	MB	Megabyte	
MSS72	MOC	Mission Operations Center	

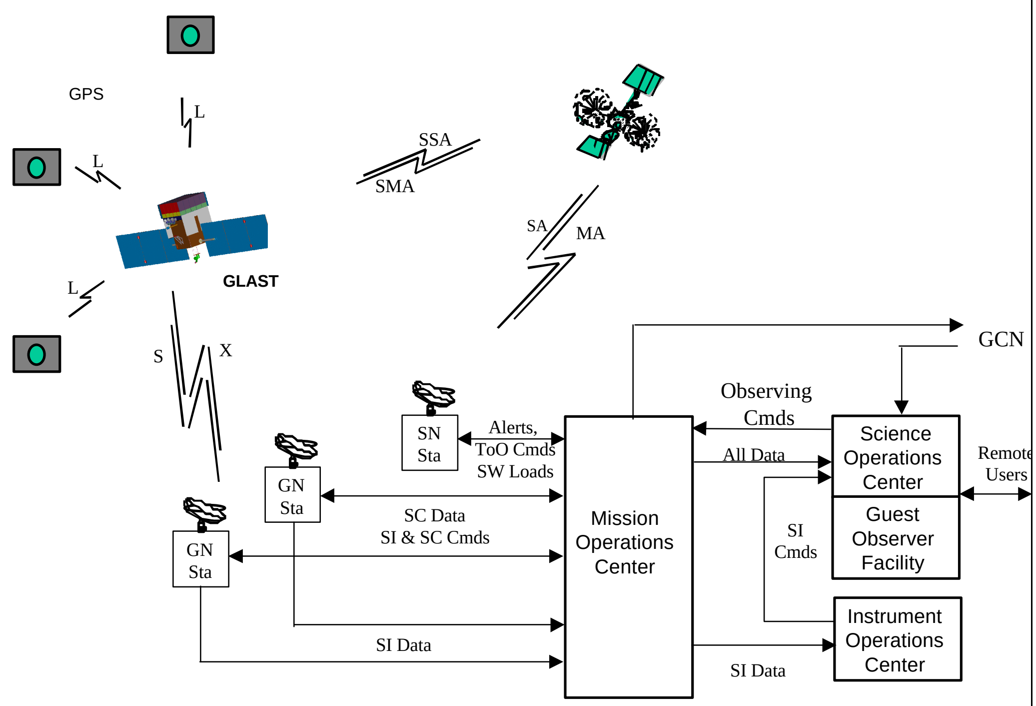
Object Identifier	MSS		Rqmt Rationale
MSS73	PB	Playback	
MSS74	RT	Real Time	
MSS75	SC	Spacecraft	
MSS76	SI	Science Instrument	
MSS77	SN	Space Network	
MSS78	SSC	Science Support Center	
MSS79	SSR	Solid State Recorder	
MSS80	TBD	To Be Determined	
MSS81	TBR	To Be Resolved	
MSS82	TDRSS	Tracking and Data Relay Satellite System	
MSS83	UL	Uplink	

MSS84	# 1 Introduction	
MSS85	## *1.1 Purpose and Scope*	
MSS86	This document responds to the Level 1 requirements for the Gamma-ray Large Area Space Telescope (GLAST) mission that will be established in the GLAST Program Plan. It also responds to the architectural requirements of the Anouncement of Opportunity for GLAST, to the science requirements that are given in the Science Requirements Document, and to the operations concept that is described in the Operations Concept Document for the mission. Implementation of these of requirements is accomplished in this document by defining the operational system that acquires the science data and by specifying the top-level requirements of the different elements of that system. These system requirements together with the requirements for the system elements and their interfaces constitute the level 2 requirements for the mission.	
MSS87	## *1.2 GLAST Overview*	
MSS88	The GLAST mission is a follow–on to the EGRET (Energetic Gamma–Ray Experiment Telescope) on the Compton Gamma Ray Observatory (CGRO). GLAST is a high–energy, gamma–ray Observatory designed to observe celestial gamma–ray sources in the approximate energy range of 20 MeV to greater than 300 GeV. A field of view of at least 2 steradian is required to make the primary Science Instrument (SI), the Large Area Telescope (LAT) particularly effective for exploring the transient nature of the high–energy gamma–ray sky. GLAST will address many fundamental astrophysical questions from a diverse population of sources – stellar mass objects, in particular, neutron stars and black holes; the nuclei of active galaxies that likely contain supermassive black holes; interstellar gas in the Galaxy that interacts with high–energy cosmic rays; the diffuse extragalactic background; supernovae that may be sites of cosmic–ray acceleration; and the mysterious gamma–ray bursts. Mission lifetime is required to be at least 5 years, with a goal of 10 years. The GLAST Observatory will be launched with a Delta 7920-10 rocket in the year 2005. During the first 1-2 years of the mission, the zenith-pointed Observatory will scan the sky from an orbit of 550 km altitude and of 28.5 degrees inclination. During the remainder of the mission, the Observatory will point to selected targets in the sky and stare at them for a specified period of time, possibly as much as several weeks at a time. Throughout the mission, whether scanning or staring, the Observatory will detect and respond to transient events, such as Gamma-Ray Bursts and flaring Active Galactic Nuclei. Within seconds of detection of a transient event, the Observatory will issue an alert message via relay satellite to the	

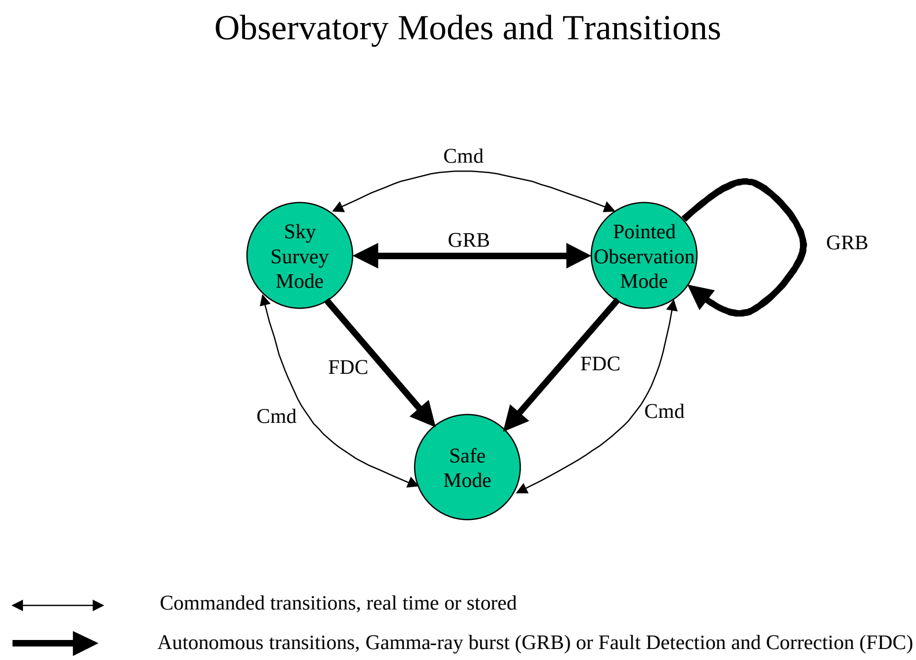
	ground. This alert message will be transmitted automatically around the world on the Gamma-ray Coordinates Network to ground based observatories. At other times, these same observatories can, in turn, notify the GLAST observatory through the Science Support Center (SSC) when they detect possibly related events at other wavelengths. The SSC may also receive alerts from other sources on the Internet. At any time during the mission, the SSC may choose to respond to such ground-generated alerts and interrupt the current mode of Observatory operation to repoint it temporarily to the new target of interest. During normal mission operations, the Observatory will operate unattended for many orbits at a time. The Observatory will monitor itself, so that it can safe itself and "call home" if it gets in trouble. In normal operation, however, it will store the continuous stream of science data that is generated at an average rate of 300 kbps. The science data will be transmitted once a day at 150 Mbps directly to a low-latitude ground station and from there at a slower rate, 1.5 Mbps, to the different operations centers. Once the data is completely assembled and time ordered by the Mission Operations Center (MOC), it will be transmitted to the Instrument Operations Centers (IOC) and to the Science Support Center (SSC). In the IOC the data are quality checked and validated. The IOC will also perform special data processing and will generate calibrations for production data processing in the SSC. The data will be archived in the SSC in a HEASARC compatible database. During the course of the mission the SSC, in conjunction with the HEASARC, will support archival research and multi-wavelength studies, which will be continued by the HEASARC in the post mission era. Standard data products, such as sky maps and catalogs, will be generated by the SSC for use by the GLAST Science Team and by Guest Observers. It is expected that mission-specific data products will also be provided.	
MSS89	***1.3 System Definition***	
MSS90	The operational concepts given in the remainder of this section are the basis for the requirements that are given in section 3. The operational system for GLAST is the end-to-end system that acquires the observational data and produces the scientific data sets. It will be operated as a facility for the science community.	
MSS91	**1.3.1 System Architecture**	
MSS92	The GLAST system is shown in hierarchical form in the architecture block diagram of Figure 1-1. Basically, the overall system is comprised of 3 segments, the flight segment (everything that flies), the ground segment, and the space-ground systems that connect flight and ground segments. This specification is organized along these architectural lines.	

MSS93		
MSS94	**Figure 1-1 Architectural Block Diagram of the GLAST System**	
MSS95	**1.3.2 Functional Description**	
MSS96	A functional configuration of the system is shown below in Figure 1-2. The design of this configuration may be affected by certain connectivity's and consolidations that are already in progress and that are scheduled for completion well before the current GLAST launch date in 2005. The most significant developments with respect to GLAST are the following:	
MSS97	IP connectivity throughout the NASA ground networks by 2001,	
MSS98	Integrated Mission Operations Center (IMOC) at GSFC by 2Q 2001,	
MSS99	Scheduling of data services consolidated at White Sands by 3Q 2001, and	
MSS100	Level zero processing performed at ground stations by 4Q 2003.	
MSS101	These may cause some functions to shift from one location to another, which will change the functional partitioning between the different operations centers.	
MSS102	Starting at the left of Figure 1-2, the GLAST observatory appears in low earth orbit, supported by the Global Positioning System (GPS) and two communications systems. The observatory consists of primary and secondary Instruments and the spacecraft. In operation the observatory acquires observational data continuously and stores it on board. During routine operations the data are transmitted to the	

	ground once per day. The GPS supports the observatory by providing orbit position and time. The observatory does not require orbit maintenance and control, but it does need orbit determination for contact scheduling and data tagging.	
MSS103	One of the communications systems is a direct link to ground system, using at least 2 ground stations, a primary and an alternate. The other communication system is a relay satellite system, viz. TDRSS. The full-view coverage of the geostationary TDRS relay satellites is used when extended contact times are needed, such as during launch and early orbit, during emergencies, during software uploads, and whenever random access times are needed, such as for gamma-ray burst alerts. For normal operations, however, transmissions of the bulk science data are able to use the intermittent, direct contacts of low latitude ground stations. Two direct link ground stations are shown in the figure to represent the complementary operations of a primary and an alternate station.	
MSS104	The ground segment is comprised of 4 operations centers, a Mission Operations Center (MOC), an IOC for the Large Area Telescope (LAT), an IOC for the Gamma-Ray Burst Monitor (GBM), and a Science Support Center (SSC), which includes a Guest Observer Facility (GOF). The MOC handles the overall operations of the observatory including health and safety of the spacecraft, the monitoring of any critical instrument engineering parameters, the generation of all command loads, and the conduct of contingency operations. The MOC also receives alerts from the observatory and forwards Gamma-Ray Burst (GRB) alerts to other observatories on the Gamma-ray burst Coordinates Network (GCN). The IOCs handle the operation of the primary and secondary instruments, including instrument health and safety, instrument configuration commanding, optimization of instrument detection and operation, and validation of instrument data. The SSC performs the observational planning for the mission, performs production data processing of the science data, and archives all mission data. In addition, the SSC coordinates requests for pointed observations from external users and from the observatories on the GCN. The GOF operates as an annex to the SSC in support of guest observer projects. These 4 centers are not constrained to be co-located. High-speed communications between all elements of the ground system will support the transfer of large volumes (10s of Gb) of data and provide access to databases in different parts of the system.	

MSS105		
MSS106	**Figure 1-2 System Architecture for GLAST**	
MSS119	**1.3.3 Modes of Operation**	
MSS120	Modes are different ways or methods of accomplishing something in contrast to a state, which is a particular instance of operation. The GLAST system employs 3 modes of operation of the observatory as seen below in Figure 1-3. Transitions between modes are commandable, and it is possible to transition from any mode to any other mode. These commands may be either immediate real-time commands, as when the spacecraft is in contact with the ground, or time delayed commands that are stored on board. Some of the transitions may be performed autonomously as well, as will be seen in the discussion below.	
MSS121	Observations are carried out in either the Sky Survey Mode or the Pointed Observation Mode. In the Sky Survey Mode the observatory is nominally zenith pointed. In this mode there is the capability of a cyclical roll offset that can be incremented every few orbits to point the observatory above and below the plane of the orbit. This motion, coupled with the wide, 2 sr, field of view of the LAT, provides full sky coverage several times per day. The observatory can run autonomously in this mode indefinitely.	

MSS122	In the Pointed Observation Mode, the observatory is commanded to point at a particular target in the sky and to hold on that target for a commanded duration. At the end of the time duration, the observatory will be commanded to the Sky Survey Mode if another pointed observation command is not pending. Sequences of stored commands may be used to carry out a sequence of pointed observations. These sequences can include alternate targets to be viewed during occultation of the primary target by the Earth.	
MSS123	Transient observations also are performed in the two observing modes. When autonomous repointing is enabled in the Sky Survey Mode, on-board detection of a GRB will cause an autonomous transition to the Pointed Observation Mode. At the same time a GRB alert message will be sent to the ground via relay satellite. The GRB alert message will be followed by real-time data, also via relay satellite, for the period of GRB observation. This period will be a commandable parameter. Upon expiration of the GRB observation time, the observatory will transition autonomously back to the Sky Survey Mode and will resume sky survey operation. Similarly, a transient observation also may be performed by a ground-generated alert command arriving via relay satellite. Such ground alert commands can carry an observation time of their own, so that there is the capability of overriding the preset observation time on board. Transient observations also may be performed from the Pointed Observation Mode. When autonomous repointing is enabled, the current pointed observation may be interrupted by an on-board detected GRB, with autonomous transitions to and from the transient target. Ground alerts can also interrupt an ongoing pointed observation. Transient observations are not provided with alternate occultation targets. An occultation of a transient target represents a loss of data for the duration of the occultation.	
MSS125	A Safe Mode is used to protect the observatory when anomalies are detected. These are faults that are not correctable by the on-board Fault Detection and Correction (FDC) capability. Autonomous transitions to the Safe Mode will occur whenever an anomaly is detected in any of the other modes. In Safe Mode the observatory is in inertial hold with its attitude referenced by the Sun. Observing is suspended in this mode, as the instruments are powered off. A safe mode alert message is generated by the autonomous transition and sent to the ground via relay satellite. Mission Operations then needs to schedule a contact to obtain housekeeping data via S-Band omni and proceed to resolve the anomaly. A ground command is necessary to exit the necessary Safe Mode and resume normal operations.	
MSS126	The LAT will have modes of its own. Different data taking modes, such as Normal (filtered data), Raw Data (unfiltered data), and Calibration (unvetoed high-energy cosmic rays) will be transparent to the SC. Others, such as, Off for South Atlantic Anomaly (SAA), and Boot Up from resets, will result in interruption of data flow and the generation of gaps. But since these can occur in any observation mode, the observatory will simply maintain its observation mode. Software loads from the ground will need to be performed under a pointing constraint in the Pointed	

	Observation Mode to ensure visibility of the relay satellite with the omni antenna. Of course, a data gap would be generated during the load and algorithm changeover.	
MSS690		
MSS128	**Figure 1-3 Observatory Modes and Transitions**	

MSS129	**2 Applicable Documents**	
MSS130	GLAST Program Plan, TBD	
MSS131	GLAST Science Requirements Document, TBD, 1999	
MSS646	Delta II Payload Planners Guide: http://www.boeing.com/defense-space/space/delta/delta2/guidelines.htm	
MSS132	CCSDS 701.0–B–1, “Recommendation for Space Data Systems Standards. Advanced Orbiting Systems, Networks, and Data Links: Architectural Specification.” CCSDS Recommendation, Blue Book, October 1989.	
MSS133	CCSDS 102.0–B–3, “Recommendation for Space Data Systems Standards. Packet Telemetry.” CCSDS Recommendation, Blue Book, October 1989.	
MSS134	CCSDS 202.0–B–2, “Recommendation for Space Data Systems Standards. Telecommand, Part 2: Data Routing Service.” CCSDS Recommendation, Blue Book, October 1989.	
MSS647	CCSDS 102.0-B-4 "Recommendation for Space Data Systems Standards. Packet Telemetry." http://www.ccsds.org/publications.html - telemetry	
MSS648	CCSDS 101.0-B-3 "Recommendation for Space Data Systems Standards. Packet Telemetry Channel Coding." CCSDS Recommendation, Blue Book.	
MSS649	CCSDS 201.0-B-2 "Recommendation for Space Data Systems Standards. Packet Telecommand, Part 1: Channel Service." CCSDS Recommendation, Blue Book.	
MSS650	CCSDS 201.0-B-1 "Recommendation for Space Data Systems Standards. Packet Telecommand, Part 2.1: Command Operation Procedures." CCSDS Recommendation, Blue Book.	
MSS651	CCSDS 701.0-B-2 "Recommendation for Space Data Systems Standards. Advanced Orbiting Systems, Networks, and Data Links: Architetctural Specification." CCSDS Recommendation, Blue Book.	
MSS135	NSS 1740.14, NASA Safety Standard, Guidelines and Assessment Procedures for Limiting Orbital Debris, August 1995.	

MSS652	GEVS-SE Rev A. General Environmental Verification Specification for STS and ELV Payloads, Subsystems, and Components. http://arioch.gsfc.nasa.gov/302/gevs-se/toc.htm	
MSS693	NPD 8010.2B, NASA Policy Directive, Use of the Metric System of Measurement in NASA Programs, (expired 1/19/00)	

MSS136	# 3 Requirements	
MSS137	## *3.1 System Requirements*	
MSS138	System requirements apply throughout the GLAST system.	
MSS139	### 3.1.1 Lifetime	
MSS140	The operational lifetime shall be a minimum of 5 years, with a goal of 10 years, following an initial 30 day (TBR) period of in–orbit checkout.	Science requirement.
MSS424	The orbital lifetime shall not exceed 25 years beyond the operational lifetime.	Max allowed pe NSS 1740.14 fo uncontrolled reentry from low earth orbit.
MSS141	### 3.1.2 Launch Date	
MSS142	The GLAST observatory will be launched in 2005 (TBR).	Project requirement
MSS143	### 3.1.3 Orbit	
MSS144	Orbit parameters for the GLAST mission are given in the following paragraphs.	
MSS145	#### *3.1.3.1 Altitude*	
MSS146	The initial orbit altitude shall be 550 km (TBR).	Initial altitude is selected to provide a mission life of 10 to 35 years for the Observatory Mass/Area ratio under conditions of plus and

		minus 2 sigma solar flux estimates for the epoch of the mission.
MSS425	Subsequently orbit altitude shall be uncontrolled, resulting in a gradual decay during the course of the mission.	
MSS426	There is no requirement for orbit maintenance.	
MSS147	***3.1.3.2 Inclination***	
MSS148	Orbit inclination shall be 28.5 degrees (TBR).	
MSS149	***3.1.3.3 Eccentricity***	
MSS150	Orbit eccentricity shall be less than 0.001 (TBR).	Eccentricity is selected to maintain the drag altitude within 10 km for background uniformity and ease of data analysis..
MSS151	**3.1.4 Serviceability/Retrieval**	
MSS152	There is no requirement for in–orbit servicing or observatory retrieval.	
MSS153	**3.1.5 Disposal**	
MSS154	At the end of mission life, the method of disposal shall be by uncontrolled reentry into the Earth's atmosphere (TBR).	
MSS155	**3.1.6 Coordinate Systems**	
MSS156	GLAST shall use the J2000 inertial coordinate system using RA and DEC as a standard means of identifying and reporting celestial objects and of communicating	For consistency among system

	pointing directions between its systems.	elements.
MSS612	**3.1.7 Units of Measurement**	
MSS613	GLAST shall observe the current NASA policy directive, NPD 8010.2B.	
MSS735	Metric units shall be used in all design calculations. English units may be used for mechanical fabrication.	
MSS157	**3.1.8 Communications Standards**	
MSS158	The GLAST program shall employ the standard communications format and protocol as recommended by the Consultative Committee on Space Data Systems for the transport of its data within the flight system, the space-ground communication systems, and the ground system.	
MSS446	Other packet transport protocols that are used in the ground system will be transparent to GLAST.	
MSS696	All space-ground communications shall be AOS compliant.	
MSS697	The GLAST system shall accommodate variable-length packets for science and housekeeping data.	
MSS171	**3.1.9 Data Loss**	
MSS172	The loss of observational science data due to operational constraints and fault recovery shall not exceed 2.0 % (TBR).	
MSS429	The loss of observational science data due to identifiable errors shall not exceed 1.0% (TBR).	
MSS173	**3.1.10 Data Quality**	
MSS174	The maximum error rate for undetected event errors in the science data stream shall not exceed 1 x 10-10.	
MSS175	**3.1.11 Data Autonomy**	
MSS176	GLAST shall use self-contained packets for its science data.	

MSS430	Each packet will be constructed at its source to contain all relevant on-board observatory data for its subsequent processing on the ground.	
MSS453	Calibration and alignment data will be constructed separately from science data sets.	
MSS1030	**3.1.12 Data Rate**	
MSS1022	The GLAST system shall accommodate an orbit averaged science data rate of 300 kbps, with a goal of 1 Mbps.	
MSS177	**3.1.13 Data Latency**	
MSS178	The system data latency shall be less than 48 hours (TBR) 95% of the time.	normal latency of 48 hrs + 3 da weekend = 120 hrs.
MSS698	The maximum data latency shall not exceed 120 hours.	
MSS699	Nominal latency allocations are as follows:	
MSS179	The on board storage data latency shall not exceed 30 hours.	
MSS180	The downlink and transmission to SSC data latency shall not exceed 12 hours.	
MSS181	The production data processing shall begin within 24 hours (TBR) of receipt of data.	
MSS1023	**3.1.14 Adaptable Detection Algorithms**	
MSS1024	The GLAST system shall support adaptable detection algorithms throughout the operational life of the mission.	
MSS182	**3.1.15 Modes of Operation**	
MSS183	The GLAST system shall have 2 operational modes, the sky survey mode and the pointed observation mode, and 1 safe mode..	
MSS103	In both operational modes, the GLAST system shall accommodate normal	

2	observation data as well as raw data.	
MSS103 3	In both operational modes, the GLAST system shall have a diagnostic capability as well as a maintenance capability.	
MSS188	***3.1.15.1 Sky Survey Mode***	
MSS189	In the Sky Survey Mode, the observatory shall scan the sky continuously.	
MSS471	In the Sky Survey Mode, the observatory shall be capable of executing cycles of incremental roll offsets.	
MSS435	Offset parameters, such as the size of offset, the number of offsets per cycle, and the number of orbits per offset, shall be commandable parameters.	
MSS190	***3.1.15.2 Pointed Observation Mode***	
MSS191	In the Pointed Observation Mode, the observatory shall reference its pointing control to inertial celestial sources.	
MSS436	The observatory shall point to a celestial target upon command.	
MSS437	The target coordinates and its observation time and duration shall be commandable parameters.	
MSS194	***3.1.15.3 Safe Mode***	
MSS195	In the Safe Mode the observatory shall reference its pointing and control to the Sun.	
MSS439	The inertial attitude of the observatory shall be adjusted to provide thermal and power safe environment.	
MSS440	The observatory shall be capable of maintaining its Safe Mode attitude indefinitely, or until commanded to an operational mode by ground command.	
MSS196	**3.1.16 Coordination with Other Observatories**	
MSS197	GLAST shall transmit (size TBD) alert messages of transient events to other observatories.	

MSS445	GLAST shall post (size TBD) alert messages of transient events from other observatories.	
MSS441	The GLAST system shall automatically transmit alerts of transient gamma-ray events, including time and arrival direction, within 5 seconds (TBR) of burst detection, 95% of the time.	
MSS444	The GLAST system shall transmit Gamma-Ray Burst and transient event alerts via the internet.	
MSS198	**3.1.17 Autonomy**	
MSS199	The GLAST system shall be capable of operating autonomously in its normal modes of operation.	This statement flows down to the different system elements
MSS454	High-voltage power supplies shall be managed (turned on and off) during SAA passages through stored commands.	This is a peer rqmt from the pı SI to the SC
MSS455	Daily telemetry contacts shall be managed by automated ground commands.	This is a MOC rqmt
MSS103 1	The observatory shall be capable of go-no go decision making in response to repointing commands from any command source.	
MSS200	**3.1.18 Sky Coverage**	
MSS201	The GLAST system shall obtain full (100%) sky coverage in the Sky Survey Mode to the level of sensitivity specified in the Science Requirements Document.	Addresses uniformity of coverage.
MSS202	The GLAST system shall be capable of acquiring full sky coverage every 3 orbits (TBR) in Sky Survey Mode.	
MSS203	**3.1.19 Observing Efficiency**	
MSS204	***3.1.19.1 Sky Survey Mode Efficiency***	
MSS205	GLAST shall obtain >70% observing efficiency (TBR) in the Sky Survey Mode.	

MSS456	25% inefficiency shall be allocated to loss of observing time in the South Atlantic Anomaly.	
MSS457	2% inefficiency shall be allocated to data loss in operations.	
MSS458	1% inefficiency shall be allocated to data loss to identifiable data corruption.	
MSS206	***3.1.19.2 Pointed Observation Mode Efficiency***	
MSS207	GLAST shall achieve >50% observing efficiency (TBR) in the Pointed Observation Mode.	Includes 30% inefficiency of Sky Survey Mode.
MSS214	**3.1.20 System Availability**	
MSS215	Availability is the probability that a system will be operational at a particular instant in time or the percentage of total time that it is operational. This pertains to the loss of observing time represented by the loss of data due to both fault correction and operational constraints. This requirement guides the fault-recovery response times.	
MSS216	Observatory availability shall be TBD %	
MSS217	MOC and space/ground networks availability shall be TBD %	
MSS218	Primary IOC availability shall be TBD %	
MSS655	Secondary IOC availability shall be TBD%	
MSS219	SSC availability shall be TBD %	
MSS222	***3.2 Flight System***	
MSS223	The flight system consists of the launch vehicle and the observatory. The observatory, in turn, consists of the spacecraft and the scientific instruments.	
MSS224	**3.2.1 Launch Vehicle**	

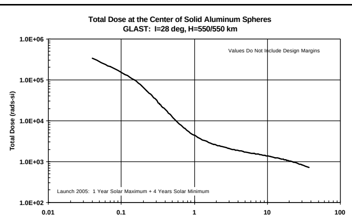
MSS521	***3.2.1.1 Provider***	
MSS522	GLAST shall use a U.S. commercial launch vehicle and launch services as required for NASA-related missions.	
MSS991	***3.2.1.2 Type***	
MSS992	GLAST shall use a Delta II 7920 launch vehicle or equivalent.	
MSS718	***3.2.1.3 Performance***	
MSS719	The launch vehicle shall place the GLAST observatory in the specified orbit with the following tolerances: TBD km in altitude, TBD degrees in inclination, and TBD fraction in eccentricity.	
MSS670	***3.2.1.4 Reliability***	
MSS211	Launch Vehicle reliability shall be 95% or greater at 50% confidence level.	Per NPD 8610.7 it is anticipated that the responsible Enterprise will categorize the GLAST payload as Risk Category 3 as mission critical to the implementation of NASA's Strategic Plan.
MSS226	***3.2.1.5 Throw Capability***	
MSS611	The launch vehicle shall have a mininum throw capability for the GLAST observatory to the specified orbit that is equivalent to a Delta II 7920 from Cape Canaveral.	
MSS730	***3.2.1.6 Fairing Diameter***	

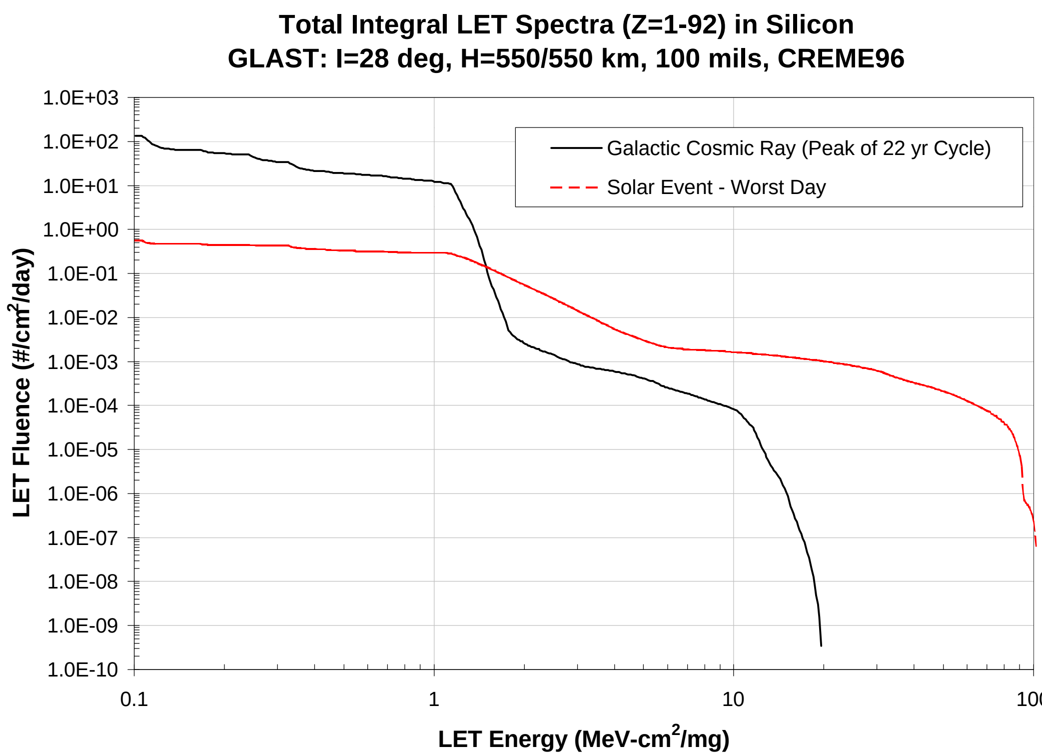
MSS731	The launch vehicle shall provide a minimum fairing diameter of 3m.	
MSS230	**3.2.2 Observatory Requirements**	
MSS987	The observatory consists of the spacecraft and the two science instruments.	
MSS705	***3.2.2.1 Observatory System Allocations*** This section allocates technical resource and performance requirements between observatory systems.	
MSS233	***3.2.2.2 Mass***	
MSS619	*3.2.2.2.1.1 Mass Total*	
MSS234	The observatory total mass at launch shall not exceed 4505 kg.	Based on lift capability of Delta 7920-10 t 550 km.
MSS620	*3.2.2.2.1.2 Mass Allocations* The following mass allocations for spacecraft and instruments include contingency.	Allocations from Mission Concep Review and AO
MSS720	The mass of the spacecraft shall not exceed 1100 kg.	
MSS721	The mass of the LAT shall not exceed 3000 kg.	
MSS722	The mass of the secondary instrument shall not exceed 75 kg (TBR).	Interrim allocation pending outcom of spacecraft accommodation study 2000.
MSS723	The mass allocated to payload attach fitting differentail is 40 kg.	
MSS724	The mass allocated to project reserve is 290 kg (TBR).	Interrim allocation pending outcom of spacecraft accommodation

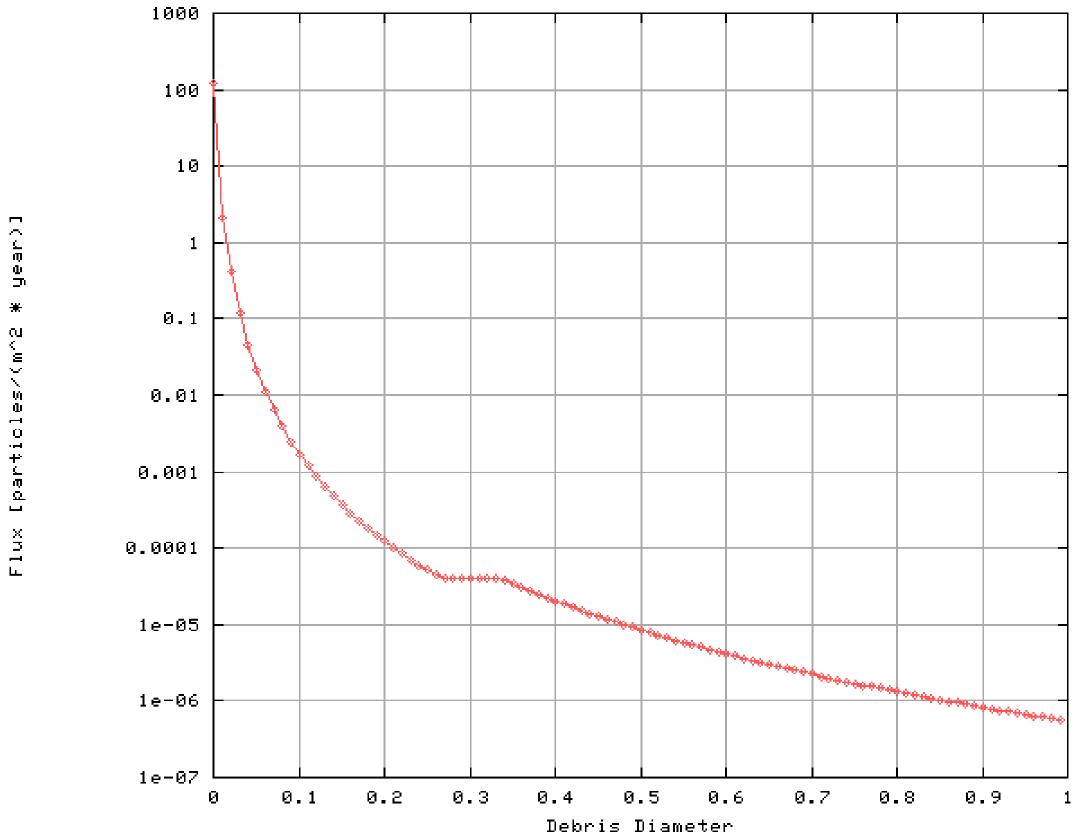
		study 2000.
MSS235	**_3.2.2.3 Power_**	
MSS634	_3.2.2.3.1.1 Power Total_	
MSS236	Orbit average power for the observatory shall not exceed 1.2 kW during the operational lifetime of the mission.	Based on packaging study and the desire not to drive size and cost of solar arrays.
MSS635	_3.2.2.3.1.2 Power Allocations_ The following power allocations for orbit average power include contingency.	Allocations from Mission Concep Review and AO
MSS725	The orbit average power for the spacecraft shall not exceed 400 W.	
MSS726	The orbit average power for the LAT shall not exceed 650 W.	
MSS727	The orbit average power for the GBM shall not exceed 50 W.	
MSS728	The orbit average power allocated to project reserve is 100 W.	
MSS695	3.2.2.3.2 Time Accuracy	
MSS617	The observatory shall maintain Universal Time Coordinated (UTC) to an absolute accuracy of 10 µseconds with a goal of 2 µseconds.	SRD rqmt
MSS700	The allocation of time accuracy is as follows:	
MSS253	The spacecraft shall maintain UTC time to an accuracy of 1 µs.	SC portion of SRD overall 2 µ goal. The GPS capability of 337 ns allows us to design to the SRD goal.
MSS618	The primary SI shall maintain UTC time to an accuracy of 1 µs.	SI allocation of SRD 2 µs goal.

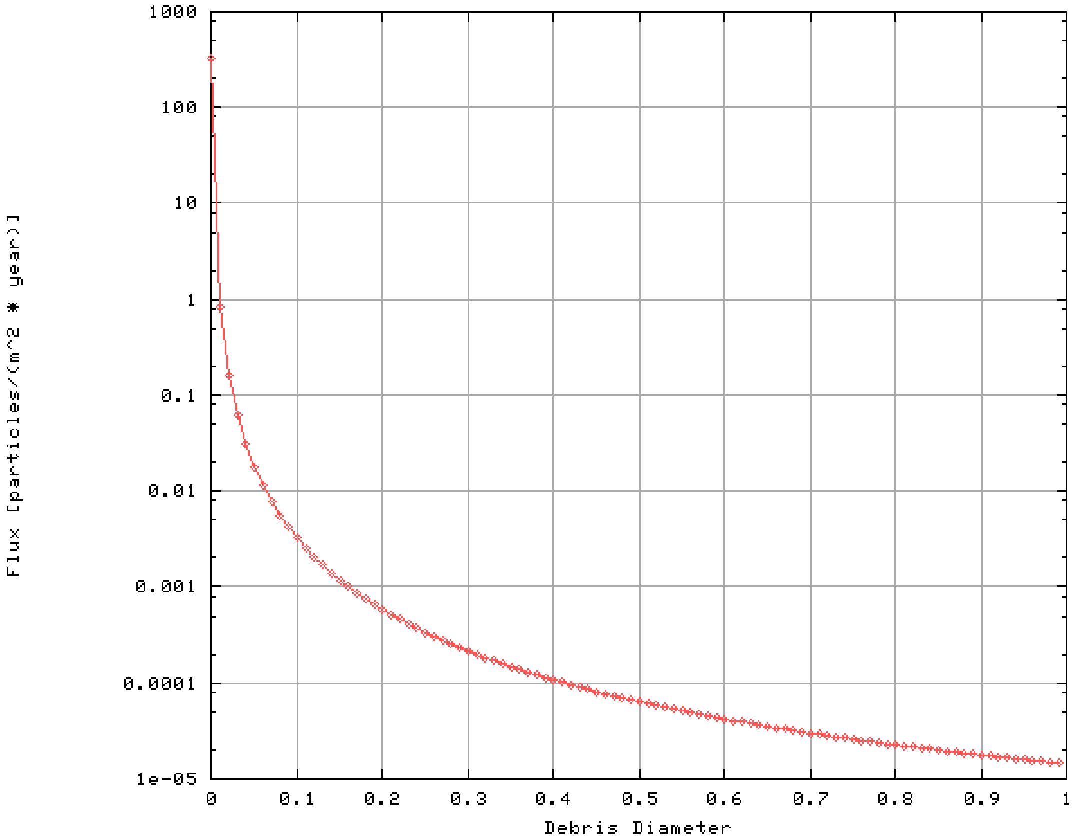
MSS208	**3.2.3 System Reliability**	
MSS209	System reliability is defined here as the probability that the mission will not suffer a mission-ending failure. This pertains to the flight system only, as space-ground communications and the ground system are considered assured. This requirement guides the selection of components and the implementation of redundancy.	
MSS210	The GLAST observatory shall achieve an overall reliability of > 80 % at 5 years. Reliability allocations are as follows:	20% degradatio max required by SRD
MSS212	Spacecraft reliability shall be 89 % (TBR) or greater.	SC in series w/ LAT, therefore equal reliab. rqmt. Rsrd > Rsc X Rlat
MSS213	Primary instrument reliability shall be 89 % (TBR) or greater.	
MSS654	GBM reliability shall also be 89 % (TBR) or greater.	commensurate w/ primary instrument
MSS729	***3.2.3.1 Observatory System Requirements***	
MSS694	3.2.3.1.1 Pointing Coordinates	
MSS653	Pointing commands to the observatory and pointing directions reported by the observatory shall be by Right Ascension (RA) and Declination (Dec) in J2000 coordinates.	
MSS241	***3.2.3.2 Pointing Accuracy***	
MSS242	The observatory pointing and control absolute accuracy shall be less than 10 arcminutes (TBR), 1 s diameter	Typo in the web version of the SRD. Actual requirement in signed version is 10 arcmin (0.5 degree, 3 sigma) Also, SRD says

		diameter, not radial.
MSS243	***3.2.3.3 Pointing Knowledge***	
MSS244	The observatory pointing knowledge shall be less than 10 (TBR) arcsec, 1 σ diameter.	SRD says diameter Allocations between SI and SC are TBD.
MSS1017	3.2.3.3.1 Repointing	
MSS1018	*3.2.3.3.1.1 Field of View*	
MSS1019	For purposes of repointing the observatory shall use a conical field of view of 55 degrees (TBR) half angle.	
MSS245	***3.2.3.4 Position Accuracy***	
MSS246	Orbital position of the observatory shall be known to an accuracy of less than 1 km (TBR) at all times.	Accommodates, but reflects ability to achieve better knowledg than, the SRD requirement.
MSS258	**3.2.4 Payload Requirements**	SI reqts have migrated to separate documents. These should capture only the information needed at the system level, descriptive info.
MSS1020	The payload shall consist of 2 scientific instruments, the Large Area Telescope (LAT), and the Gamma-ray Burst Monitor (GBM).	

MSS259	***3.2.4.1 Large Area Telescope***	
MSS272	The LAT shall meet the performance requirements that are given in the Science Requirements Document.	
MSS988	*3.2.4.1.1.1 Gamma-Ray Burst Monitor*	
MSS990	The GBM shall meet the performance requirements for GRB burst detection as given in the Science Requirements Document.	
MSS747	3.2.4.1.2 Space Environmental Estimates	
MSS748	*3.2.4.1.2.1 Charged Particle Radiation*	
MSS749	This section gives the total dose and single event upset (SEU) requirements for the charged particle radiation environment.	
MSS750	3.2.4.1.2.1.1 Total Dose	
MSS751	The total dose for a 5-year mission in the GLAST orbit, beginning in 2005, is given by the dose-depth curve in Figure 3-9.	
MSS752		
MSS753	**Figure 3-9.** Total Dose-Depth Curve.	
MSS754	3.2.4.1.2.1.2 Total Dose Design Margin	
MSS755	A multiplicative factor of 2 shall be applied to the total dose estimate for estimate uncertainty, and an additional factor of 2.5 (TBR) shall be applied to achieve an overall design margin of 5. Shielding shall be designed and parts chosen to yield the required design margin.	
MSS756	3.2.4.1.2.1.3 LET Spectrum	

MSS757	The LET energy spectrum for direct ionization by heavy ions is given in Figure 3-10.	
MSS758		
MSS759	**Figure 3-10.** LET Spectra.	
MSS760	3.2.4.1.2.1.4 Single Event Effects Immunity	
MSS761	Electronic parts shall be selected for immunity to single event effects. All parts shall be selected for immunity to single event latch-up. A linear energy threshold of 8 MeV/mg/cm^2 (TBR) shall be used as a guideline to select parts for reasonably low probability to single event upset due to proton induced secondary.	
MSS762	*3.2.4.1.2.2 Meteoroid and Debris Flux*	
MSS763	3.2.4.1.2.2.1 Meteoroid Flux	
MSS764	Figure 3-11 gives the meteoroid flux at 550 km. The meteoroid environment encompasses only particles of natural origin. The average mass density for all meteoroids is 0.5 grams (g) per cubic centimeter, and the average velocity for all meteoroids is 20 kilometers per second. The meteoroid flux is from the NASA	

	SSP-30425 (1991) model that can be found at http://envnet.gsfc.nasa.gov.	
MSS765		
MSS767	**Figure 3-11.** Meteoroid Environment at 550 km. Debris Diameter is in cm.	
MSS768	3.2.4.1.2.2.2 Debris Flux	
MSS769	Figure 3-12 gives the debris flux at 550 km. The orbital debris environment is composed of residue from man-made satellites and launch vehicles. The average velocity for objects smaller than 1 centimeter is 10 km/sec, and the average mass density is 2.8 g/cm^3. This flux is from the Orbital Debris Model, also found at http://envnet.gsfc.nasa.gov. It was run with the following parameters:	
MSS770	Debris Diameter (cm) varied,	
MSS771	Altitude 550 km,	
MSS772	Inclination 28.5 degree,	
MSS773	Year 2005,	
MSS774	Traffic Growth Rate 5%,	

MSS775	Small Object Growth Rate 2%,	
MSS776	SolarFlux 147.13	
MSS777		
MSS780	**Figure 3-12**. Debris Environment at 550 km. Debris Diameter is in cm.	
MSS783	***3.3 Space-Ground Systems***	
MSS835	**3.3.1 Global Positioning System**	
MSS837	The GPS consists of the constellation of GPS satellites in 12-hour orbits and their master control center.	
MSS836	GLAST shall utilize the Standard Positioning Service of the Global Positioning System (GPS) to determine its position and time.	
MSS785	**3.3.2 Space Network**	

3.3.2.1 MSS786		
MSS997	3.3.2.1.1 Non-routine Operations	
MSS787	The Space Network shall provide command and telemetry communications for launch, in-orbit checkout, and contingency operations.	
MSS791	***3.3.2.2 Software Loads***	
MSS792	The Space Network shall support uploads of large blocks (1 MB) of software to the GLAST primary Instrument. The data rate will be 4 kbps. A telemetry data stream via the SN will be used to monitor the receipt of the loads.	
MSS788	***3.3.2.3 On-Demand Communications***	
MSS789	The Space Network shall provide on-demand transmissions of alerts of celestial events to the GLAST Observatory from the MOC. The data rate will be 250 bps.	
MSS790	The Space Network shall provide on-demand transmissions of alerts (celestial events and safe mode) from the GLAST Observatory to the MOC. The data rate will be 1 kbps.	

MSS793	**3.3.3 Ground Stations**	
MSS794	GLAST shall utilize the services of existing ground stations. These ground stations will be multi-mission stations, and GLAST will be one of several missions supported by them.	
MSS795	***3.3.3.1 Availability***	
MSS796	During early orbit checkout, and on other "infrequent" (TBD) occasions during the mission, the GN stations shall be available for contacts on every orbit for several (TBD) days at a time.	
MSS797	During normal mission operations, the GN stations shall be available for daily contacts on at least 3 (TBR) successive orbits.	
MSS798	***3.3.3.2 Reliability***	
MSS799	At least 1 GN station shall be available every day of the mission.	
MSS800	The ground network stations shall deliver 98.5% of the data scheduled to be downlinked to the GLAST ground data system.	
MSS801	***3.3.3.3 Automation***	
MSS802	Each GLAST GN station shall be capable of operating with an unattended MOC. (This capability is required to support "lights out" operation on weekends.)	
MSS803	***3.3.3.4 Link Communications***	
MSS804	Each GN station shall be equipped to provide simultaneous S-band and X-band support on the same contact.	
MSS983	The GN stations shall provide S-band uplink at 2 kb/s	
MSS984	The GN stations shall provide normal S- band downlink at 32 kb/s.	
MSS985	The GN stations shall provide emergency S-band downlink at 4 Mb/s.	
MSS986	The GN stations shall provide normal X-band downlink at 150 Mb/s.	

MSS819	***3.3.3.5 Data Handling***	
MSS820	Each GN station shall perform the following data handling functions.	
MSS821	3.3.3.5.1 Capture	
MSS822	The GN station shall capture downlink S-band data and downlink X-band data. This includes demodulation, bit and frame synchronization, and error detection and correction.	
MSS823	3.3.3.5.2 Buffering	
MSS824	The ground station shall buffer the most recent data for at least 7 days.	
MSS825	The ground station will retransmit data within 7 days to the MOC or LAT IOC upon request	
MSS826	3.3.3.5.3 Accounting	
MSS827	The GN station shall identify frames that are missing and frames with uncorrectable errors.	
MSS828	The ground station shall provide accounting data to the MOC in real time.	
MSS829	3.3.3.5.4 Distribution	
MSS830	The ground station shall separate the virtual channel associated with the LAT and send this data to the LAT IOC within 12 (TBR) hours of receipt.	
MSS831	The ground station shall send real time 32 kbps S-band data to the MOC in real time.	
MSS832	The ground station shall send playback spacecraft data and GBM data virtual channels to the MOC within 6 (TBR) hours of receipt.	
MSS833	***3.3.3.6 Commanding***	
MSS834	The GN station shall uplink commands and data from the MOC.	

MSS838	**3.4 Ground System Requirements**	
MSS839	The ground system consists of serveral interconnected operating centers, a Mission Operations Center (MOC), an Instrument Operations Center (IOC) for the LAT and for the GBM, and a Science Support Center (SSC). It is expected that the MOC will be a multi-mission operations center, while the other centers will be mission unique.	
MSS840	**3.4.1 Security**	
MSS998	The operations centers shall be interconnected by an intranet of wide area networks that is closed to, or protected from, public users of the external internet.	
MSS1005	**3.4.2 Compatibility**	
MSS1006	All elements of the ground system shall be compatible with the variable length formats of the science data packets.	
MSS883	**3.4.3 External Interfaces**	
MSS1000	***3.4.3.1 Space-Ground Link***	
MSS1004	The MOC shall be the sole interface between the elements of the ground system and the space-ground communications links.	
MSS1001	***3.4.3.2 GPS***	
MSS1007	The ground system shall determine observatory orbit independently using observatory GPS telemetry.	
MSS1002	***3.4.3.3 GCN***	
MSS1008	The ground system shall interface with the Gamma-ray Coordinates Network for communications of alerts of celestial events with other observatories.	
MSS1009	***3.4.3.4 HEASARC***	

MSS1010	The ground system shall interface with the the High Energy Astrophysics Science Archive Research Center (HEASARC) in support of multi-wavelength studies.	
MSS1003	***3.4.3.5 External Users***	
MSS1011	The ground system shall interface with external users of the GLAST system to support of observing plans and archival research	
MSS909	**3.4.4 Performance**	
MSS1012	***3.4.4.1 Data Quality***	
MSS999	Each operations center shall maintain the quality of science data in the transmission and processing of the data.	
MSS1013	***3.4.4.2 Latency***	
MSS1014	The ground system shall meet the latency requirements for routine data transmission and processing as allocated in 3.1.13.	
MSS1015	***3.4.4.3 Operational Efficiency***	
MSS1016	The ground system shall operate the observatory to meet the requirements for observing efficiency of the mission.	